

HISTORICAL NOTE ON CUMULATIVE RECORDERS MANUFACTURED IN JAPAN

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The history of cumulative recorders manufactured in Japan between the early 1970s and the present is described. The first such instrument was the Tosoku-Kogyo Company's Model T-45A, followed thereafter by its Model T-45B, built on the same chassis as the T-45A, but with different electrical and mechanical components. When Tosoku-Kogyo closed its recorder operations, the recorder continued to be manufactured and sold by Okubo-Sokkouki as its Model OS 180. The appearance of such commercially manufactured cumulative recorders in countries other than the United States further attests to the internationalization of behavior analysis during the mid- to late-20th century.

Key words: cumulative recorder, Japanese manufacture, history

In a recent review of the history of the cumulative recorder, Lattal (2004) briefly described a cumulative recorder that was manufactured in Japan, but few details of its history were presented. Here we provide a fuller story of that recorder, which begins in 1969 when the first author borrowed from Professor Takashi Ogawa of Keio University a cumulative recorder that may have been sent to that university in the 1950s. (Skinner [1983, p. 38] mentions that Ralph Gerbrands sent some operant conditioning apparatus to Japan in 1952. In 1976, C. B. Ferster recounted to the first author that he personally arranged for a shipment of operant conditioning apparatus to Keio University in the 1950s. Whether or not that recorder was the same one sent as part of either of these shipments—or whether they were, in fact, the same shipment—is unconfirmed.) Whatever its history, the cumulative recorder received by Ogawa resembled a Gerbrands Model C-1 cumulative recorder in that it had a similar gravity-type reset mechanism and a similar response-pen excursion mechanism, but this recorder was housed in a

wooden box and had a very different response-pen reset mechanism from the C-1. (Lattal noted that a cumulative recorder housed in a wooden box was mentioned by several individuals involved in laboratory work in the experimental analysis of behavior in the United States during the 1950s and 1960s.)

The first author borrowed this wooden box cumulative recorder from Ogawa in 1969 to use in his research at the Primate Research Institute at Kyoto University. At that time, American-manufactured cumulative recorders were expensive in Japan because of the high exchange rate between the Japanese yen and the U.S. dollar (360 yen fixed to the dollar, as opposed to the current floating rate of approximately 102 yen to the dollar) in addition to high taxes and shipping costs. When the first author investigated importing a Gerbrands recorder in those years, the estimated price shown by an import firm was about 300,000 yen (approximately \$833.00). Searching for reliable alternatives, the Institute in 1969 placed an order with the Tosoku-Kogyo (an amalgam for “Tokyo-sokuteiki,” with the latter word meaning “measurement equipment” in Japanese) company to make a cumulative recorder under the supervision of the first author. Tosoku-Kogyo manufactured measurement instrumentation for different industries, particularly the pharmaceutical industry. They also manufactured custom-made equipment for psychological research. Working with Mr. Shohaku Okubo, an engineer who ran his own company, Okubo-Sokkouki, which was a subcontractor of Tosoku-Kogyo, the first version (identified as T-45A) was developed. It was modeled after the

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above-mentioned wooden box recorder and then manufactured beginning in the early 1970s.

Figure 1 shows a T-45A (see also Lattal, 2004, Figure 24, for other views of the recorder). (All capital letter references below are to the letters that appear on Figure 1.) The aluminum and steel chassis (30.2 cm wide \times 19.7 cm deep \times 15.5 cm high) is painted bluish-grey. The response-pen assembly (A) of the T-45A is attached to a continuous-loop string (B) that is wrapped around two pulleys, one (C) near the apogee of the response pen assembly and the other near the base, that is, the point to which the response pen resets (D). The string was pulled along as the result of a friction contact between the string and the pulleys. The base pulley assembly (D) is actually two independently operating pulleys stacked one atop the other (E and F). The upper base pulley (E) is attached to a rod with a gear mechanism at its terminus that is attached to another gear, which was turned by the operation of a stepping switch. Each response operated the stepping switch, which resulted in the movement along the platen of the pen assembly attached to the string. As the pen assembly moved along the platen (G), a second string (H), attached to the base of the pen assembly just below the tip of the arrow pointing to this string, simultaneously increased the tension on a spring located in the lower base pulley (F). When the pen reached its apogee, a microswitch was triggered. This in turn operated a solenoid that activated a reciprocating arm attached to the base pulley assembly (D), angling the pulley slightly toward the center of the platen. The solenoid that operated the reciprocating arm is visible at I. This action released the tension on the string responsible for moving the pen assembly along the platen, allowing the spring to pull the pen assembly back to the base of the platen. When the pen assembly returned to its base position, a second microswitch deactivated the solenoid, releasing the reciprocating arm and reinstating tension on the string attached to the base of the pen assembly. Gollub, recalling an early cumulative recorder he saw at Harvard University in the late 1950s, observed that, on that recorder: "Reset was accomplished by a reciprocating arm that pulled the pen carriage back to the starting position" (quoted in Lattal, 2004,

p. 340). Gollub's description sounds similar to the reciprocating arm action of the T-45A.

In addition to the response pen assembly, a second, event-pen assembly could be attached in a stationary position below the resting position of the response-pen assembly. Each pen (response and event) was attached via narrow-gauge plastic tubing to a small metal ink reservoir located at the top left rear of the recorder (J).

The platen (G) was longer than the Gerbrands platen (200 mm versus 180 mm for a Gerbrands Model C3). The T-45A used 180-mm wide paper marked with a grid (see Figure 2). The paper also was manufactured in Japan. The range of the response pen before resetting was 150 mm, cumulating 750 responses. Two paper speeds, 5 mm/ or 15 mm/min, could be selected by setting a switch on the top of the recorder (K). (A manual switch control over paper speed never appeared on the Gerbrands recorders—paper speed changes required changing the gears attached to the paper-drive motor.)

A final, striking, characteristic of the T-45A is its weight, approximately 8.12 kilograms (without paper) as opposed to 5.31 kilograms for a Gerbrands Model C-3 recorder. The weight difference is due at least in part to the heavy reciprocating-arm solenoid, which requires a strong chassis for support, as opposed to the light spring/clutch reset mechanism on the Model C-3 (and later model) Gerbrands recorders.

The T-45A was used in major Japanese universities such as Waseda University and Keio University. One of the recorders used at Waseda is now in the behavior research apparatus collection at West Virginia University (Lattal, 2004). The first publication reporting data generated with a T-45A was that of Ito (1975). Subsequently Asano and Fantino (1976) reported on the responding of Japanese monkeys (*Macaca fuscata fuscata*) under a variety of reinforcement schedules (VI, VR, FI, and FR). Figure 2 shows a cumulative record generated by a T-45A of the responses of one of the latter monkeys where responding under a fixed-ratio 100 schedule was reinforced by the delivery of single soybeans.

Approximately 20 T-45A recorders were manufactured and each sold for 160,000 yen, about half of the cost of the imported Gerbrands recorder at that time. The record-

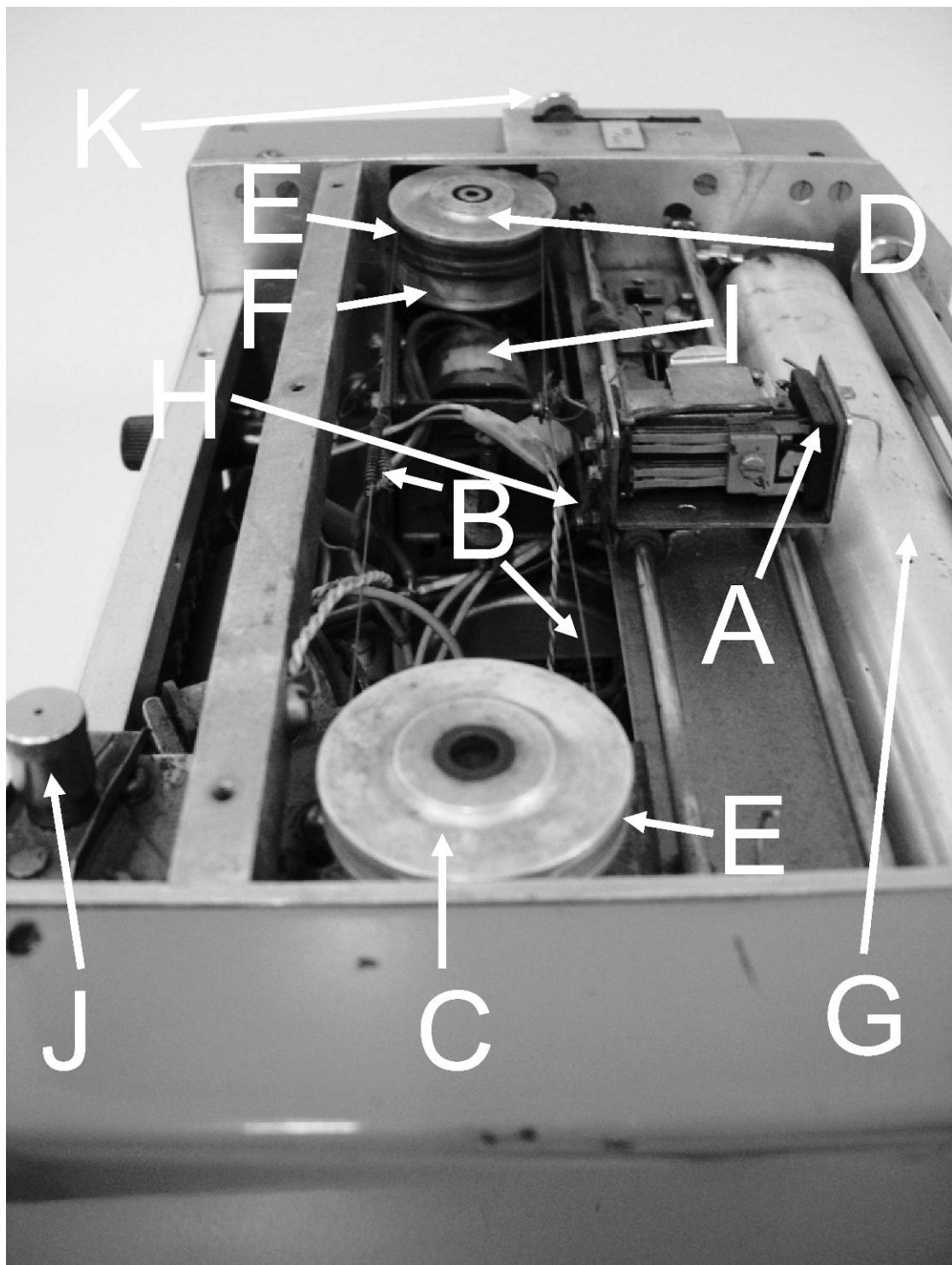


Fig. 1. A Model T-45A cumulative recorder. The left side panel of the recorder is directly in front of the viewer, with the front of the recorder to the reader's right. Each letter points to a component described in the text.

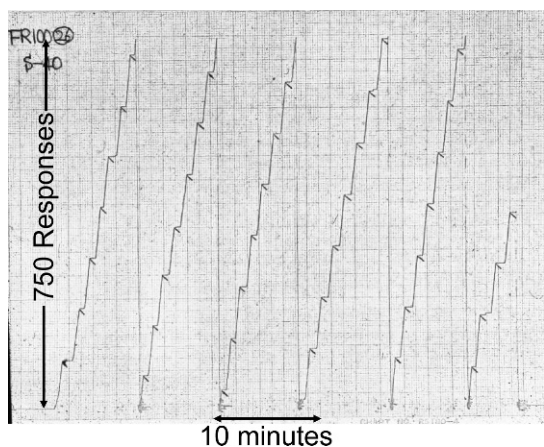


Fig. 2. Cumulative record generated by a Model T-45A cumulative recorder. Details of the record are described in the text.

ers were purchased by researchers in psychology, neurophysiology, and also those in the pharmaceutical industry in Japan. They were reliable enough in terms of the movement of the response pen and paper. Several problems with the recorder, however, have been noted. The ink in the pens would dry and the plastic tube did not siphon the ink reliably. Whether this was a design problem or something else is not clear. The correct ink and its mixing apparently was a problem for several laboratories, as it was discussed in several early technical notes published in the *Journal of the Experimental Analysis of Behavior* (Lindsley, 1958; Russell, 1961; Verhave, 1958). Two difficulties with the ink reservoir are that it is small and made of metal. The latter precludes easy visual access to the ink level. (Similar reservoir systems were standard on some U.S.-manufactured cumulative recorders, e.g., the ones manufactured by the Scientific Prototype Company used a clear plastic ink reservoir). The noise of the ratchet/stepping relay mechanism that stepped the response pen and the noise made when the reset mechanism was activated was a disturbance in some experimental settings. Even more problematic was the electrical noise produced by the response pen and reset mechanisms, which interfered with data collection in investigations where physiological changes were being recorded concurrently with responding under different environmental contingencies. Also, the many heavy-duty parts responsible for the

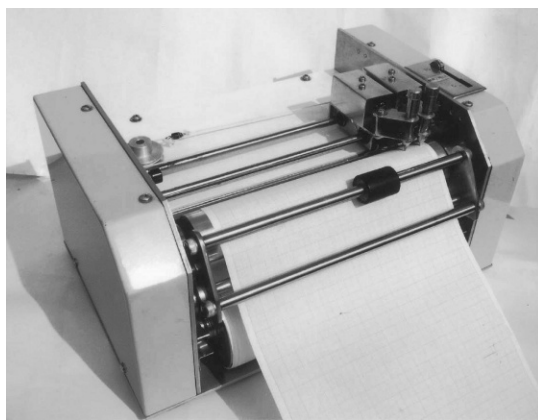


Fig. 3. A Model T-45B/OS 180 cumulative recorder.

various functions of the recorder required significant maintenance.

In response to these shortcomings of the T-45A, a new model of the recorder was designed around 1976. Two design sheets for this recorder, provided by Mr. Okubo, are in the behavioral research apparatus collection at West Virginia University. One, showing the electronic circuitry of the recorder, is dated April 3, 1976. The other, showing exterior views of the frame, is dated 1978 and the design number "OS-180B-1" appears at the bottom of the sheet. On this latter sheet, however, the diagram clearly shows the label "T-45B" on a drawing of the back panel of the recorder. According to Mr. Okubo, Okubo-Sokkouki manufactured the T-45B recorders sold by Tosoku until they closed their division for psychological research apparatus for use with animals in the 1980s. At that time, Okubo-Sokkouki continued to manufacture and sell the T-45B, but under its own model number, the OS 180. The company still manufactures the OS 180 and services both.

A photograph of the OS 180/T-45B appears as Figure 3. This particular recorder was manufactured in 1986 and still is being used for behavioral research at Tokiwa University (e.g., Kubota & Moriyama, 2007). Its outward appearance is similar to its predecessor the T-45A, but its engineering was different. The T-45B replaced the solenoid drive system for the excursion of the response pen assembly (which, in this photograph, holds a felt-tipped pen) along the platen with a stepping motor of the sort used on contemporary computer printers. The stepping motor allowed control

of the rotation of direction and angle, and hence the length of the pen step. The rotation speed was controlled by the frequency of the electrical pulse that operated the stepping motor. Using a solid-state circuit, it was able to control the stepwise movement of the pen and also permit a smooth, rapid return of the response pen to the home position. This reset function was accomplished by capitalizing on the capability of the stepping motor to quickly reverse directions. In the earliest Gerbrands recorders, presumably including the wooden box one used as a model for the T-45A, the gravity-based reset mechanism was not reliable and eventually was replaced by the spring/clutch reset mechanism mentioned above (cf. Lattal, 2004). The use of the pulse motor overcame the same problem of unreliable reset in a different way, and, unlike the Gerbrands solution, did so with minimal noise, either ambient or electrical.

During 1980s, the exchange rate and related costs had dropped to the point that it became economical to import cumulative recorders from the United States. The Primate Research Institute and other Japanese universities supplemented or replaced their T-45A or T-45B recorders with Gerbrands Model C-3s. Soon thereafter, as in the United States, inexpensive personal computer systems began to replace the conventional controlling and recording equipment of animal laboratories in Japan.

Several operant laboratories in Japan, however, continue to prefer the OS-180 and its customized iterations to American recorders or to computer displays of cumulative records. Their continued use is based on their simplicity and reliability, and is facilitated by the availability of parts and repair services, unlike the now extinct Gerbrands and other commercially manufactured cumulative recorders in the U.S. The records generated by cumulative recorders have not for decades served as the primary data in behavioral research, and earlier versions of experiment control equipment have

been replaced by computers. Nonetheless, these records, and the recorders that generate them, continue to have didactic value in monitoring both moment-to-moment changes in responding and the operation of the controlling computer programs and interfacing. By these means, they provide to students valuable lessons in the exquisite interplay between subtle environmental and subsequent behavioral changes. Of course, such monitoring also might be accomplished using a cumulative record on a computer screen. Cumulative recorders like the ones described in this note, however, infuse these lessons with a sense of the history of the experimental analysis of behavior that computers cannot offer. More broadly, these cumulative recorders manufactured in Japan also are, literally, "hard data" reflecting the internationalization of behavior analysis during the mid- to late-20th century.

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